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(71)Applicant : SUMITOMO METAL IND LTD
(72)Inventor : KONDO KUNIO
OSAKO HAJIME

(54) PRODUCTION OF SEAMLESS STEEL TUBE

(57)Abstract:
PROBLEM TO BE SOLVED: To produce a seamless steel tube minimal in the dispersion of mechanical properties, excellent in weldability, and having high strength and high toughness by performing specific direct quench-and-temper treatment at the time of hot rolling for a steel having a composition in which specific amounts of C, Si, Mn, Al, and optional elements are contained and the amounts of impurities are controlled.

SOLUTION: A steel, which has a composition containing, by weight, 0.02-0.15% C, 0.1-1.5% Si, 0.5-2% Mn, and 0.001-0.5% sol.Al, also containing, as optional elements, prescribed amounts of Cr, Mo, Ni, Ti, Nb, V, Zr, Ca, Cu, and B, and having the balance Fe with inevitable impurities in which respective amounts of P, S, N, O, etc., are controlled, is used. This steel is subjected to hot piercing and rolling and worked into seamless steel tube. At this time, the steel tube is finished at ≥40% reduction of area at 800-1050°C and allowed to stay in the state in a heating furnace of 850-1100°C for 3sec to 30min. Then, the steel tube is directly hardened at R°C/sec average cooling rate to 800-500°C, represented by inequality I. Further, the steel tube is tempered under the conditions represented by inequalities II or III, according to its wall thickness t(mm).

[Claim 1]By weight %, C:0.02 to 0.15%, Si:0.1-1.5%, Mn:0.5-2%, solAl: 0.001-0.5%, Cr:0-1.5%, Mo : 0 to 1.5%, nickel: 0-2.5%, Ti:0-0.08%, Nb : 0 to 0.08%, 0 to 0.3%, Zr:0-0.08%, Ca : V: 0 to 0.01%, Cu : The remainder consists of Fe and inevitable impurities including 0 to 0.8%, and B:0 to 0.008%, In hot-rolling which processes into seamless steel tubes between heat steel which is P:0.05% or less, S:0.01% or less, N:0.01% or less, and O (oxygen):0.01% or less of inevitable impurities after punching, Finishing strip processing of not less than 40% of a section compression ratio is applied with finish

temperature of 800-1050 **, After inserting seamless steel tubes in a heating furnace then held in an 850-1100 ** temperature region and making it **** for [for / 3 seconds / -] 30 minutes, A manufacturing method of high intensity high toughness seamless steel tubes excellent in weldability annealing by tempering temperature T (**) which performs direct quenching with the average cooling rate R from 800 ** to 500 ** shown in the following ** type (**/second), and is further shown in following ** type or ** type according to thickness of a steel pipe. When making t into thickness (mm) of seamless steel tubes, it is $R>=(10^{3.1})/(t^{1.4})$. .....** When making T into tempering temperature (**), in the case of 0< t<30, the thickness t (mm) is :500-2.3xt <= T <= 720-1.1xt... In the case of **30 <=t : Ordinary temperature <= T <= 720-1.1xt ... **

[0001]
[Field of the Invention]This invention relates to the manufacturing method of the seamless steel tubes of high intensity high toughness excellent in the weldability used for investigation of a crude oil or natural gas, extraction, or a transfer, especially the seamless steel tubes used as a line pipe.

[0002]
[Description of the Prior Art]In recent years, a direct-quenching method has come to be adopted as a heat treating method of seamless steel tubes at many factories. However, even if the direct-quenching method can give high intensity and high toughness to a steel pipe with high hardenability highly [the carbon equivalent which does not need to take welding into consideration] therefore, Under the present circumstances, it is difficult to satisfy high intensity and high toughness simultaneously to the seamless steel tubes which lowered the carbon equivalent in consideration of weldability. Therefore, the seamless steel tubes for line pipes in which weldability is thought as important needed to be annealed with the hardening furnace apart from the production line, needed to install the furnace, and needed to perform the usual hardening tempering treatment. Here, after introducing "direct quenching" into equipment of the heating furnace etc. which made hardening equipment shift from a rolling line as it is after rolling, and were attached to the rolling line as it was ******** or after rolling, it is made to shift to hardening equipment here, and it says hardening ******. When telling a pipe or a steel pipe to below, seamless steel tubes are put.

[0003]In order to apply direct quenching also to the seamless steel tubes of the presentation which lowered the carbon equivalent and to give high intensity and high toughness, three sorts of remedies of the former following have been proposed.

[0004](b) How to achieve grain refining by cooling on a rolling line, reheating the steel which once carried out the ferrite transformation, and carrying out a reverse transformation to austenite in order to improve toughness. the method (JP,56-3626,A.) of finishing with rough rolling and specifically performing cooling and reheating in the middle of rolling JP,4-21721,A, JP,5-255749,A, JP,5-255750,A, and the method (JP,58-91123,A, JP,58-104120,A) of performing cooling and reheating after final finishing

rolling are indicated.

[0005]However, this method has large energy expenditure, and since complicated and high equipment of construction costs is needed, compared with the conventional reheating hardening method, the merit of so big facility cost and operating cost is not brought about.

[0006](**) After processing it from a viewpoint of carrying out minuteness making of the crystal grain in a non-recrystallizing temperature region, Reheat, consider it as a detailed recrystallization grain, and after that Finishing rolling, direct quenching, The method of annealing is shown (JP,6-172854,A, JP,6-172855,A, JP,6-172857,A, JP,6-172858,A, JP,6-184635,A, JP,6-184636,A, JP,6-184711,A). This method acquires a detailed recrystallization grain, when a shear strain ingredient introduces a larger processing distortion than usual in a non-recrystallizing temperature region and carries out reheating rolling after that by one skew rolling machine or two large sets.

[0007]However, in order that this method may introduce a big processing distortion, the skew rolling in a low temperature region produces the problem of making tube-manufacturing cracks occur frequently from usual. in order to perform the last rolling in a recrystallizing temperature region -- reheating temperature -- an elevated temperature -- not setting up -- it did not obtain but there was a tendency for the minuteness making by skew rolling not to be utilized enough.

[0008](**) The proposal which restricts the heating conditions after punching rolling to JP,61-238917,A strictly, makes it recrystallize not less than 90%, and obtains fine texture is made. However, since the processing conditions of seamless steel tubes are not indicated at all, this method can carry them out sure enough by the plug mill method and the mandrel method which are methods of rolling the usual seamless steel tubes, or they are not in **.

[0009]Generally, in applying direct quenching to the steel pipe of chemical composition with low hardenability, the following problem occurs besides the above-mentioned problem.

[0010](a) It is hard to obtain a uniform hardening organization over the whole seamless steel tubes (baked nonuniformity), and, as a result, mechanical properties vary along with a steel pipe longitudinal direction in profit.

[0011](b) It is strongly influenced by thick change of seamless steel tubes, and bordering on a certain thickness, when thicker than it, mechanical properties deteriorate greatly. even when the thickness used as the boundary has a the same presentation, it is changed by a manufacturing machine meeting.

[0012]The above-mentioned (a) And (b) In the case of lowering-both-chemical composition which thought weldability as important, i.e., carbon equivalent, and

hardenability steel, the width of dispersion becomes large.

[0013]
[Problem(s) to be Solved by the Invention]The purpose of this invention is to provide the manufacturing method of the seamless steel tubes by the direct-quenching tempering treatment which controlled dispersion in mechanical properties, though it is the presentation which made hardenability low in order to make weldability good.

[0014]Here, "weldability is excellent" means fulfilling that weld cracking sensitivity is low and that the toughness of a weld zone is [both] good. Also in any of the heat affected zone (HAZ:Heat Affected Zone) whose base material is the position as for which 1-5 mm of alligators entered, it says that toughness is good from the bond and bond which mean the interface to which a weld metal and a base material touch "the toughness of a weld zone is good."

[0015]
[Means for Solving the Problem]This invention persons investigated with emphasis on chemical composition, a strip-processing method, a heating method in front of direct quenching, and a hardening cooling rate, in order to improve the aforementioned technical problem. The result checked that good and uniform mechanical properties were acquired over the whole seamless steel tubes, when a suitable hardening device performed direct quenching after the whole steel pipe heating by specific heating apparatus attached to proper strip processing and a rolling line and having been annealed by specific conditions. An outline of this method is summarized as follows.

[0016](A) Minuteness making of a crystal grain by strong processing : perform processing of not less than 40% of a section compression ratio at 800-1050 ** after punching by the finishing rolling method for performing both extension and rolling in one. Sufficient processing distortion is introduced into seamless steel tubes by not less than 40% of this processing, when seamless steel tubes are ****(ed) for [for / 3 seconds / -] 30 minutes by furnace held at 850-1100 **, recrystallization is promoted, minuteness making of the crystal grain is carried out, and toughness is raised.

[0017](B) Heating of the whole steel pipe in front of direct quenching : let heating apparatus attached to a rolling line be a heating furnace with a size which heats uniformly the above-mentioned whole seamless steel tubes which carried out strong processing at a stretch. For this reason, inclination of dispersion of mechanical properties covering the whole steel pipe, especially mechanical properties of a longitudinal direction decreases remarkably.

[0018](C) A cooling rate of direct quenching : make a cooling rate in direct quenching more than a fixed cooling rate according to thickness. Though it is the presentation of this cooling rate, a hardenability improved effect peculiar to a direct-quenching method, and conjointly low hardenability, even a thick thick steel pipe can be manufactured, simultaneously, it will have a margin and comparatively thin thick seamless steel tubes with much production quantity can also be manufactured. Even if thickness is thick, a

method of securing a fixed cooling rate is mentioned later.

[0019]Tempering conditions : (D) Drawing 1, Seamless steel tubes manufactured by this invention method. Influence of tempering temperature on yield strength of (0.07%C-0.22%Si-1.3%Mn-0.01%P-0.001%S-0.27%Cu-0.08%nickel-0.05%Cr-0.032%Nb-0.023%Ti-0.035%solAl-0.0013%Ca). It is a drawing which expresses. According to the figure, with low tempering temperature, although it is low compared with a steel pipe of thin meat, yield strength of heavy-gage seamless steel tubes becomes the same value as a steel pipe of thin meat in 650-700 **, since a fall of yield strength is loose, even if tempering temperature rises. Therefore, in order to manufacture from a heavy-gage steel pipe of the same intensity level to a light-gage steel pipe by direct-quenching annealing with the same steel, tempering temperature presupposes that it is high to a light-gage steel pipe, and presupposes at a heavy-gage steel pipe that it is low. It becomes unnecessary to prepare by this how many kind thing billet which changed a presentation according to thickness, and reduction of physical distribution cost also becomes possible simultaneously.

[0020]It was completed by combining a thermomechanical treatment method of steel and seamless steel tubes which was excellent in weldability, and this invention makes a gist a manufacturing method of seamless steel tubes characterized by heat-treatment and direct-quenching annealing in front of the following presentation, hot-rolling, and direct quenching.

[0021]By weight %, (1) C:0.02 to 0.15%, Si:0.1-1.5%, Mn: 0.5-2%, solAl:0.001-0.5%, Cr : 0 to 1.5%, Mo: 0-1.5%, nickel:0-2.5%, Ti : 0 to 0.08%, Nb: 0-0.08%, V:0 to 0.3%, Zr : 0 to 0.08%, Ca: 0-0.01%, Cu : 0 to 0.8% and B:0 to 0.008% are included, The remainder consists of Fe and inevitable impurities, and among inevitable impurities P:0.05% or less, In hot-rolling which processes into seamless steel tubes between heat steel which is S:0.01% or less, N:0.01% or less, and O (oxygen):0.01% or less after punching, Finishing strip processing of not less than 40% of a section compression ratio is applied with finish temperature of 800-1050 **, After inserting seamless steel tubes in a heating furnace then held in an 850-1100 ** temperature region and making it **** for [for / 3 seconds / -] 30 minutes, A manufacturing method of high intensity high toughness seamless steel tubes excellent in weldability annealing by tempering temperature T (**) which performs direct quenching with the average cooling rate R from 800 ** to 500 ** shown in the following ** type (**/second), and is further shown in following ** type or ** type according to thickness of a steel pipe.
[0022]When making t into thickness (mm) of seamless steel tubes, it is $R>=(10^{3.1})/(t^{1.4})$. .....** When making T into tempering temperature (**), in the case of 0< t<30, the thickness t (mm) is :500-2.3xt <= T <= 720-1.1xt... In the case of **30 <=t : Ordinary temperature <= T <= 720-1.1xt ... "finishing strip processing" in a ** this invention method, processing -- influence -- direct -- a crystal grain -- minuteness making -- contributing -- the range -- strip processing -- saying -- a postscript -- carrying out -- as -- " -- elongation rolling -- processing -- " -- and -- " -- rolling -- a culmination -- it can set -- usual -- finishing -- strip processing -- " -- both -- containing . "Finish temperature" means temperature immediately after finishing rolling. it remains as it is after finishing

strip processing -- inserting in a heating furnace means inserting in a heating furnace after finishing strip processing, "without once cooling" to a room temperature. If it does not once cool to a room temperature, descaling, strain reform, etc. may be performed.

[0023]In this invention method, after finishing rolling, when seamless steel tubes are inserted in a heating furnace, all the portions of seamless steel tubes are put into a heating furnace, and it heats to a predetermined temperature.

[0024]The average cooling rate R from 800 ** to 500 ** is a cooling rate in a wall thickness center position. Finish temperature in hot-rolling is the temperature based on thick similarly.

[0025]Tempering temperature in the case of not less than 30-mm thickness says as [annealing / ordinary temperature /, i.e., direct quenching,].

[0026]
[Embodiment of the Invention]1. chemicals **** -- explain the reason which limited chemical composition in this manufacturing method first. A presentation displays weight % on below.

[0027](a) Essential element C:C is an element required to improve hardenability and raise intensity. At less than 0.02%, hardenability is insufficient and high yield strength is not obtained. However, since weld cracking sensitivity will become high if it exceeds 0.15%, it may be 0.02 to 0.15%.

[0028]Although Si:Si is an element which raises resistance to temper softening, if it becomes superfluous, the toughness of a weld zone will be reduced. Although it is required 0.1% or more for the improvement in resistance to temper softening, since toughness degradation of a weld zone is remarkable when it exceeds 1.5%, it may be 0.1 to 1.5%.

[0029]Mn:Mn improves hardenability, and it adds it in order to consider it as a predetermined organization and to secure intensity and toughness with direct quenching. Since toughness will deteriorate on the contrary if an effect is not acquired clearly but the content exceeds 2% on the other hand in less than 0.5%, it may be 0.5 to 2%.

[0030]solAl(acid meltable aluminum): solAl says that to which aluminum which exceeds the Al quantity reacted to oxygen during refinement or coagulation remained to the steel which completed coagulation. Since the dissolution N harmful to prevention of pinhole generating under coagulation or immediately after coagulation and toughness is fixed as AlN, solAl is made to remain. Even if aluminum works to deoxidation enough and the great portion of oxygen is removed during refinement, the pinhole where solAl after containing a small amount of oxygen in the solidified steel and completing coagulation is minute immediately after coagulation at less than 0.001% cannot be prevented from occurring. Immobilization of N harmful to toughness also becomes insufficient. Since

toughness will fall if **** and solAl exceed 0.5% when, it may be 0.001 to 0.5%.

[0031](b) It is not necessary to add the element which carries out the arbitrary element following. However, since it has a respectively useful effect, the more outstanding performance can be given by making a suitable quantity contain according to an element.

[0032]Cr:Cr is an element useful although hardenability is improved. Since hardenability indispensable only of an essential element is secured, it is not necessary to add Cr. However, when applying to a more nearly heavy-gage steel pipe, it is used in order to secure required hardenability. If a Cr content is made into 0.02% or more when adding, since the effect which raises resistance to temper softening other than hardenability will also be acquired, it is desirable to consider it as 0.02% or more. However, since the toughness of a weld zone will fall if it exceeds 1.5%, it may be 1.5% or less.

[0033]It is not necessary to add Mo:Mo. However, in addition to an essential element, it is used when raising hardenability and resistance to temper softening further in the case of a heavy-gage steel pipe. It is desirable for the content to consider it as 0.02% or more in less than 0.02%, since these effects are not acquired clearly. However, since toughness degradation of a weld zone will become remarkable if it exceeds 1.5%, it may be 1.5% or less.

[0034]It is not necessary to add nickel:nickel. Since nickel has an effect which improves the toughness of the matrix (base) of steel in a dissolution state, it is used when acquiring the more outstanding toughness by being stabilized. Since a hardenability improved effect will also be acquired if the content is made into 0.05% or more when adding, it is desirable to consider it as 0.05% or more. However, since improvement in toughness corresponding to the rise of alloy cost will not be obtained if it exceeds 2.5%, it may be 2.5% or less.

[0035]It is not necessary to add Ti:Ti. Since Ti forms carbon nitride in steel, prevents organization big and rough-ization of a weld zone and a toughness improvement has an effect, it adds, when securing the more outstanding weld zone toughness. Since it will be effective also against grain refining of a base material and the toughness of a base material will be improved if the content is made into 0.005% or more when adding, it is desirable to consider it as 0.005% or more. However, since the fall of base metal toughness is remarkable on the contrary when it exceeds 0.08%, it may be 0.08% or less.

[0036]It is not necessary to add Nb:Nb. Nb expands a non-recrystallizing temperature region to an elevated temperature in the case of rolling. If the crystal grain which recrystallizes after rolling and grows if Nb is not included contains Nb, it extends accumulating processing distortion with rolling, and recrystallization sets during heating before direct quenching, and a crystal grain becomes fine and is effective in the improvement in toughness. Since the effect which anneals and raises resistance to temper softening by the secondary deposit of NbC at the time will also be acquired if the content is made into 0.005% or more when adding in addition, it is desirable to consider it as 0.005% or more. However, since the toughness of a weld zone will deteriorate

remarkably if it exceeds 0.08%, it may be 0.08% or less.

[0037]V: It is not necessary to add V. Since V deposits at the time of the afterbaking return which carried out direct quenching and resistance to temper softening is raised, it is used when raising yield strength further. Since the effect of also making hardenability improving besides resistance to temper softening will also be acquired if the content is made into 0.01% or more when adding, it is desirable to consider it as 0.01% or more. However, since toughness will deteriorate greatly if it exceeds 0.3%, it may be 0.3% or less.

[0038]It is not necessary to add Zr:Zr. Since Zr generates stable carbon nitride and controls the grain growth at the time of steel (billet) heating before punching also at an elevated temperature, it is used, when carrying out minuteness making of the crystal grain further and raising toughness. When using it, since it is effective also in the improvement in toughness of a weld zone if 0.005% or more, it is desirable to consider it as 0.005% or more. However, since the toughness fall of a base material is remarkable when it exceeds 0.08%, it may be 0.08% or less.

[0039]It is not necessary to add Ca:Ca. Ca reacts to S in steel and generates a sulfuration thing in molten steel. Unlike MnS etc., this sulfuration thing is not extended to a rolling direction with strip processing, and after rolling is spherical. For this reason, since weld cracking or the hydrogen induction crack (HIC:Hydrogen Induced Cracking) which makes the tip etc. of the extended inclusion the starting point of a crack is controlled, it is used when controlling weld cracking or a HIC crack.

[0040]When using it, since there is an effect also in the improvement in toughness of a weld zone when 0.0002% or more, it is desirable to consider it as 0.0002% or more. However, since base metal toughness will fall and a crack will be frequently occurred to a steel pipe surface simultaneously if it exceeds 0.01%, it may be 0.01% or less.

[0041]It is not necessary to add Cu:Cu. Since Cu is effective in an intensity rise and corrosion-resistant improvement, it is used when the much more high yield strength and high corrosion resistance are required. When using it, if 0.05% or more, since the hardenability in direct quenching will also be improved, it is desirable to consider it as 0.05% or more. However, since hot-working nature will fall if it exceeds 0.8%, it may be 0.8% or less.

[0042]B: It is not necessary to add B. Since B improves the hardenability at the time of direct quenching remarkably in a minute amount, it is used, when improving hardenability in a heavy-gage steel pipe, or when reducing Mn of an essential element, etc. from the standpoint of corrosion resistance and toughness and compensating a part for the hardenability fall. When using it, if 0.0002% or more, since the effect which forms BN by a weld zone further and fixes the dissolution N harmful to toughness as BN will be acquired, it is desirable to consider it as 0.0002% or more. However, if it exceeds 0.008%, since the toughness of a base material and a weld zone will be injured, it may be

0.008% or less.

[0043](c) The element of the inevitable-impurities following mentions some impurities mixed unescapable. If it does not control within the limits of the following, calling it inevitable impurities, sufficiently good performance is not obtained.

[0044]P: P exists unescapable in steel as an impurity. Since a segregation will be carried out to a grain boundary and toughness will be fallen to it if it exceeds 0.05%, it may be 0.05% or less.

[0045]S: Mix S as well as P in steel as an impurity. Since sulfides, such as big and rough MnS, will be generated, it will extend with hot-rolling and HIC-proof nature and toughness will be reduced if it exceeds 0.01%, it may be 0.01% or less.

[0046]N: Steel exists as an impurity, and since N deteriorates especially the toughness of a weld zone, it may be 0.01% or less.

[0047]O(oxygen): Since O exists in steel as an impurity, ductility and toughness are fallen and a surface flaw is generated, it may be 0.01% or less.

[0048]2. Explain the reason for having set the following manufacturing conditions as steel of the chemical composition which thought as important the weldability which carried out the manufacturing-conditions above.

[0049](a) Heating and punching of steel : as described above, as long as it is what is called a billet that carried out continuous casting to the thing which carried out slabbing to round bar shape, or the round shape mold, and was manufactured, what kind of thing may be sufficient as the steel inserted in a heating furnace. For energy reduction, after slabbing or continuous casting, a billet may be inserted in a heating furnace, before cooling thoroughly to a room temperature.

[0050]The cooking temperature of a billet should just be the temperature which can carry out hot working with a boring machine. The optimal temperature changes with construction material and is defined in consideration of high temperature ductility and high-temperature-deformation resistance. Usually, it is desirable to heat in the range of 1100-1300 **. In order to realize highly efficient billet heating, let billet length be a long picture of the integral multiple of predetermined length. Before performing after-heating punching, it is desirable to cut to predetermined length with the cutting machine installed in the latter part (preceding paragraph of a boring machine) of the heating furnace.

[0051]In punching, a breakthrough is opened in the billet of inner substance between heat, and a hollow element tube (hollow shell) is manufactured. There are skew rolling, press punching, etc. in a perforation method, and it does not limit in particular. If the skin temperature of a billet falls, since it will become easy to generate a crack at the time of punching, an auxiliary heating device, for example, an induction heating apparatus, may

be installed just before punching.

[0052](b) Elongation rolling processing and finishing strip processing : extend and adjust the size of the punched hollow element tube with elongation rolling processing and finishing strip processing, and manufacture the seamless steel tubes of desired shape. Compared with processing with a boring machine, it becomes processing in a low temperature region comparatively. If it finishes before processing distortion given by the stretching process is recovered, and it rolls, the processing distortion of a stretching process is also included as processing distortion of finishing-on parenchyma rolling, and can be used for the minuteness making of the organization by processing. In this specification, "the section compression ratio in finishing rolling" means after punching "the section compression ratio which doubled processing in the both sides of a stretching process and finishing strip processing." A section compression ratio means (tube cross section product after tube cross section product-processing before processing)/(tube cross section product before processing).

[0053]In this invention, the finish temperature of the range of 800-1050 ** needs to perform the above-mentioned "finishing strip processing" of not less than 40% of a section compression ratio. With a section compression ratio, at less than 40%, recrystallization does not advance smoothly and a sufficiently detailed crystal grain is not obtained. In particular since the maximum of a section compression ratio changes with the construction material and mill capability of a pipe to manufacture, it does not limit, but as for a section compression ratio, since it will become easy to generate a crack on the surface if a section compression ratio exceeds 80%, it is desirable not to exceed about 80%. Since a crystal grain will become big and rough and a fine grain organization will not be obtained if result rolling temperature exceeds 1050 **, it may be 1050 ** or less.

[0054]On the other hand, at less than 800 **, although a recrystallization grain becomes detailed like low temperature, since it becomes difficult for the deformation resistance of an element tube to become large and to perform processing of not less than 40% of a section compression ratio, finish temperature makes rolling finish temperature not less than 800 **.

[0055]What is necessary is to dissociate conventionally and just to consider the elongator arranged independently and a finishing mill as the arrangement which carried out continuation unification, in order to finish before processing distortion given by the stretching process after punching is recovered, and to roll. The section compression ratio of finishing rolling of the seamless steel tubes of all the sizes can be made into not less than 40% on parenchyma by continuation unification.

[0056]By restraining the back end of the mandrel bar which is an inner surface regulation tool after the end of elongation rolling, the mandrel mill as elongator pulls back a mandrel bar to the mill ON side, and just carries out the cyclic use of waste water. In particular, it is preferred that the pull back speed of a mandrel bar is the mill which became independent of the movement speed of the hollow element tube under elongation

rolling.

[0057]The sizer as a finishing mill should not just have an inner surface regulation tool. It is desirable to use what is called an extra KUTINGU sizer provided with the function which pulls out a mandrel bar and is separated from the pipe rolled especially by the mandrel mill.

[0058](c) Heat-treatment : it is the big feature of this invention to heat-treat in order to advance recrystallization after finishing rolling and before direct quenching. During heating, recrystallization is induced and a crystal grain carries out minuteness making. Since this invention method does not perform strip processing after heating unlike the method of finishing with the conventional rough rolling and heating between rolling, cooking temperature can be set as the minimum temperature to which recrystallization advances. For this reason, a very detailed recrystallization grain is acquired.

[0059]A long time is taken for recrystallization to complete cooking temperature at less than 850 ** in the case of the low carbon low alloy steel which thinks as important the weldability made into the object of this invention method, and productive efficiency falls.

[0060]On the other hand, since a crystal grain will become big and rough remarkably if it exceeds 1100 **, cooking temperature shall be 850-1100 **.

[0061]On the occasion of this heating, I have to introduce all the portions of seamless steel tubes into the heat treating furnace maintained at the above-mentioned temperature, and all the portions must be made to stay for [for / 3 seconds / -] 30 minutes in a furnace simultaneously. For less than 3 seconds, since the grain which ended recrystallization will grow and become big and rough if recrystallization does not advance enough but exceeds for 30 minutes, in-furnace time is carried out for [for / 3 seconds / -] 30 minutes. It is for correcting dispersion in the temperature before direct quenching, and raising the homogeneity of the temperature of a steel pipe longitudinal direction especially to introduce all the portions of seamless steel tubes in a furnace at a stretch, and to make them **** for [for / 3 seconds / -] 30 minutes.

[0062]With such heating, the homogeneous improvement in the temperature of the longitudinal direction (rolling direction) of seamless steel tubes and dispersion control of the hardening temperature for every rolling mill meeting are attained simultaneously with the minuteness making of the crystal grain which is the original purpose.

[0063]Direct-quenching tempering treatment : (d) In this invention method. After rolling, since a steel pipe is heated by 850-1100 ** as it is after rolling, even if some steel pipes carry out a temperature reduction, it becomes lower than Ar_3 point and generates a ferrite, it is introduced into a heating furnace and all the portions of a steel pipe are austenitized again easily. For this reason, it becomes easy for it to be stabilized and to supply the steel pipe of homogeneous performance in actual operation.

[0064]In the case of chemical composition with low hardenability which thought weldability as important, depending on the usual hardening treatment, it becomes a ferrite subject's hardening organization, and the good hardening organization where martensite and detailed bainite were intermingled is not obtained. Although the direct-quenching method of hardenability improves compared with the usual hardening process, only by an improved part of this hardenability, it is stabilized and a good hardening organization is not obtained. In order to apply, to be stabilized in steel of chemical composition with low hardenability which thought weldability as important and to consider direct quenching as a good hardening organization at it, the cooling rate R must be made into the cooling rate of the range of following ** type.

[0065]
$R>=10^{3.1}/t^{1.4}$.....** However, R is an average cooling rate (**/second) from 800 ** to 500 **, and t is the thickness (mm) of a steel pipe.

[0066]In order to consider it as such a cooling rate, it is insufficient that seamless steel tubes are just immersed in a tank. ** The cooling rate with which it is satisfied of a formula passes a high-pressure jet stream inside, for example, rotating a steel pipe, and the outside surface is possible by arranging many nozzles to a steel pipe longitudinal direction, and passing a lamina stream.

[0067]When thickness is less than 30 mm, in order to use moderate intensity and toughness, the organization which got with direct quenching is annealed at the temperature below Ac_1 point. Tempering temperature is annealed at the temperature T (**) shown in the following ** type according to the thickness t (mm) of a steel pipe.

[0068]
500-2.3xt <= T <=720-1.1xt ... When ** thickness is not less than 30 mm, intensity reservation is thought as important and it anneals with the tempering temperature with which it is satisfied of the following ** types also including the case where it does not anneal.

[0069]
Ordinary temperature <= T <= 720-1.1xt ... the minimum of the tempering temperature in ** type in case ** thickness is less than 30 mm, In a temperature lower than it, intensity becomes high too much, toughness becomes insufficient, and when it anneals at the temperature to which the maximum of tempering temperature exceeds it, intensity reservation is because it becomes difficult.

[0070]It is because as [direct-quenching] is required for having considered tempering temperature as as [beyond ordinary temperature, i.e., direct quenching,] at the thickness of not less than 30 mm in order to secure intensity, and is because intensity reservation will become difficult if the upper limit temperature shown in ** type is exceeded.

[0071]
[Example]Table 1 is a table showing the chemical composition of the steel used in order

to carry out this invention, and steel of a comparative example. Table 2 is a table showing P of the inevitable impurities of these steel, S, N, and O (oxygen). These steel was ingoted with a 70-t converter, and was processed into the round billet through usual ingot making and cogging process.

[0072]
[Table 1]

表　1　(wt%)

	鋼	C	Si	Mn	Cr	Ni	Mo	Cu	Ti	Nb	V	Zr	sol.Al	B	Ca
本発明例	A	0.11	0.49	1.15	—	—	—	—	—	—	—	—	0.022	—	—
	B	0.05	1.20	1.21	0.03	1.52	—	—	—	—	—	—	0.032	—	—
	C	0.07	0.33	1.18	—	—	—	—	0.04	0.03	—	—	0.043	—	0.0023
	D	0.02	0.37	1.20	—	—	0.80	—	—	—	—	—	0.048	—	—
	E	0.10	0.37	1.28	0.05	—	0.05	—	—	—	—	0.04	0.022	—	—
	F	0.11	0.50	0.84	—	—	—	—	0.06	—	0.06	—	0.012	—	0.0026
	G	0.08	0.24	0.99	0.07	—	—	—	—	—	—	—	0.041	—	—
	H	0.01	0.49	1.35	0.43	0.04	—	0.28	0.05	0.04	—	—	0.035	0.0015	—
	I	0.11	0.22	1.31	—	—	—	—	—	—	—	—	0.023	—	—
比較例	Q	*0.17	0.188	1.84	—	—	—	—	—	—	—	—	0.0440	—	—
	R	0.08	*1.62	1.486	—	*2.76	—	—	—	—	—	—	0.0359	—	—
	S	0.06	0.387	0.983	*1.68	—	0.23	—	—	0.03	—	0.02	0.0184	0.0021	—
	T	0.10	0.344	1.021	0.07	—	*1.69	—	—	—	—	—	0.0433	—	—
	U	0.09	0.48	1.36	—	0.54	—	*1.09	—	—	—	—	0.024	—	0.0022
	V	0.08	0.25	1.27	—	0.28	—	*0.92	*0.14	—	*0.42	—	0.026	0.0008	0.0019
	W	0.07	0.29	1.33	0.98	—	0.45	—	0.04	*0.09	—	—	0.015	—	—

マーク*を付した数値は本発明の範囲外であることを示す。

[0073]

[Table 2]

表　2　(wt%)

	鋼	P	S	N	O
本発明例	A	0.03	0.003	0.002	0.009
	B	0.02	0.002	0.007	0.007
	C	0.02	0.003	0.008	0.006
	D	0.02	0.002	0.002	0.002
	E	0.02	0.002	0.007	0.004
	F	0.02	0.001	0.007	0.010
	G	0.02	0.001	0.009	0.003
	H	0.02	0.001	0.008	0.007
	I	0.03	0.004	0.002	0.009
比較例	Q	0.02	0.002	0.002	0.010
	R	0.02	0.002	0.009	0.004
	S	0.02	0.002	0.004	0.007
	T	0.02	0.002	0.003	0.010
	U	0.02	0.003	0.002	0.002
	V	0.02	0.002	0.003	0.003
	W	0.02	0.003	0.002	0.002

[0074]Table 3 is a table showing rolling and the heat treatment condition which were performed to these round billets. The exam shows the test condition for investigating how many dispersion of yield strength are controlled over the whole seamless steel tubes by

this invention method.
The numbers P1-P4 are the specimen.

[0075]The workability in "the workability of punching" in these tables and the "degree of finishing strip processing" displays, the percentage reduction, i.e., the section compression ratio, of the cross-section area of a billet (inner substance) or a hollow element tube (hollow shell). Result rolling temperature is the value which presumed the temperature of the central part by calculation based on measurement by a surface emission pyrometer. The cooling rate in direct quenching is the value calculated by performing interpolation or extrapolation from the cooling rate in the main thickness surveyed so far.

[0076]
[Table 3]

表　3

	番号	鋼	加熱温度(℃)	穿孔の加工度(%)	仕上げ圧延加工度(%)	仕上がり温度(℃)	加熱処理温度(℃)	加熱在炉時間(分)	肉厚t(mm)	800-500℃平均冷却速度(℃/秒)	K(℃/秒)	焼戻し温度(℃)	L(℃)	M(℃)
本発明例	P1	A	1200	55	70	840	920	10	10	73	50.1	660	477.0	709.0
	P2	A	1200	30	45	930	920	10	40	14	7.2	540	—	676.0
比較例	P3	A	1200	55	70	840	* —	*—	10	73	50.1	660	477.0	709.0
	P4	A	1200	30	45	930	* —	*—	40	14	7.2	540	—	676.0

・マーク* を付した欄は、本発明法の条件から外れることを示す。
・$K=10^{3.1}/t^{1.4}$ ：(℃/秒) 、L=500−2．3×t ：(℃) 、M=720−1．1×t ：(℃)

[0077]The specimens of the numbers P1-P4 manufactured according to the manufacturing conditions of Table 3 are seamless steel tubes 178 mm in diameter, and 12 m in length. Seven positions, a, b, c, d, e, f, and g, were defined from the edge of a winding instrument 2 m of every longitudinal directions of these steel pipes, every 90 hoop direction four points (1, 2, 3, 4) were decided about these each position, the test piece for tensile test was extracted in parallel with a tube axis, and dispersion in yield strength was investigated. That is, it asked for the yield strength of 28 positions from one steel pipe.

[0078]K in front here $10^{3.1}/t^{1.4}$ (**/second: t thickness (mm)) which is a lower limit of the average cooling rate in 800 to 500 ** in this invention, 720-1.1xt (**) whose M is the upper limit of tempering temperature again about 500-2.3xt (**) whose L is a lower limit of the tempering temperature in the case of less than 30 mm of board thickness in this invention is expressed.

[0079]Table 4 - 6 is a table showing the conditions which manufacture the specimen for investigating improvement in the intensity by applying this invention method, toughness, and weldability. Specifically, the examination described below was done.

[0080]
[Table 4]

表　4

	番号	鋼	加熱温度(℃)	穿孔の加工度(%)	仕上げ圧延加工度(%)	仕上がり温度(℃)	加熱処理温度(℃)	加熱在炉時間(分)	肉厚 t (mm)	800-500℃平均冷却速度(℃/秒)	K (℃/秒)	焼戻し温度(℃)	L (℃)	M (℃)
本発明例	1	A	1200	55	80	820	900	5	6	111	102.5	650	486.2	718.4
	2	A	1200	55	65	830	900	5	10	62	50.1	640	477.0	709.0
	3	A	1200	40	80	840	900	5	12	45	38.8	640	472.4	706.8
	4	A	1200	40	70	840	900	5	20	23	19.0	600	454.0	698.0
	5	A	1200	30	80	880	900	5	24	19	14.7	550	444.8	693.6
	6	A	1200	30	55	900	900	5	35	15	8.7	400	—	681.5
	7	A	1200	30	40	930	900	5	45	10	6.1	520	—	670.5
	8	B	1250	60	75	860	980	0.5	7	145	82.6	650	483.9	712.3
	9	B	1250	60	70	895	980	0.5	10	65	50.1	640	477.0	709.0
	10	B	1250	45	70	910	980	0.5	14	40	31.3	640	467.8	704.6
	11	B	1250	45	65	930	980	0.5	18	35	22.0	600	458.6	700.2
	12	B	1250	30	60	950	980	0.5	25	21	13.9	550	442.5	692.5
	13	B	1250	30	50	1010	980	0.5	40	15	7.2	350	—	676.0
	14	B	1250	30	40	1030	980	0.5	50	11	5.3	—	—	665.0
	15	C	1220	70	70	860	1020	1	5	152	132.3	650	488.5	714.5
	16	C	1220	70	55	895	1020	1	9	65	58.1	640	479.3	710.1
	17	C	1220	70	40	910	1020	1	14	35	31.3	640	467.8	704.6
	18	C	1220	50	60	930	1020	1	20	24	19.0	600	454.0	698.0
	19	C	1220	50	45	950	1020	1	27	17	12.5	550	437.9	690.3
	20	C	1220	40	55	1010	1020	1	35	13	8.7	400	—	681.5
	21	C	1220	40	45	1030	1020	1	45	10	6.1	—	—	670.5
	22	D	1150	70	70	845	890	15	8	99	68.5	650	481.6	711.2
	23	D	1150	70	50	860	890	15	12	52	38.8	640	472.4	706.8
	24	D	1150	50	65	910	890	15	20	34	19.0	640	454.0	698.0

$K=10^{3.1}/t^{1.4}$：(℃/秒)、$L=500-2.3\times t$：(℃)、$M=720-1.1\times t$：(℃)

[0081]

[Table 5]

表　5

	番号	鋼	加熱温度(℃)	穿孔の加工度(%)	仕上げ圧延加工度(%)	仕上がり温度(℃)	加熱処理温度(℃)	加熱在炉時間(分)	肉厚t(mm)	800-500℃平均冷却速度(℃/秒)	K(℃/秒)	焼戻し温度(℃)	L(℃)	M(℃)
本発明例	25	D	1150	50	40	930	890	15	27	28	12.5	600	437.9	690.3
	26	D	1150	40	60	950	890	15	35	14	8.7	550	—	681.5
	27	D	1150	40	45	970	890	15	45	12	6.1	—	—	670.5
	28	E	1100	60	70	860	860	30	9	82	58.1	650	479.3	710.1
	29	E	1100	60	55	910	860	30	14	45	31.3	640	467.8	704.6
	30	E	1100	60	60	930	860	30	20	28	19.0	640	454.0	698.0
	31	E	1100	40	55	950	860	30	31	14	10.3	580	—	685.9
	32	E	1100	40	40	970	860	30	40	11	7.2	—	—	676.0
	33	F	1260	70	60	890	950	5	7	117	82.6	650	483.9	712.3
	34	F	1260	50	75	940	950	5	20	35	19.0	640	454.0	698.0
	35	F	1260	40	55	1000	950	5	35	19	8.7	570	—	681.5
	36	F	1260	40	40	1030	950	5	48	13	5.6	—	—	667.2
	37	G	1220	70	70	870	920	10	5	136	132.3	650	488.5	714.5
	38	G	1220	50	70	920	920	10	18	40	22.0	640	458.6	700.2
	39	G	1220	40	60	960	920	10	30	23	10.8	600	—	687.0
	40	G	1220	40	40	990	920	10	45	12	6.1	—	—	670.5
	41	H	1250	70	65	880	900	15	8	80	68.5	650	481.6	711.2
	42	H	1250	50	70	940	900	15	18	38	22.0	640	458.6	700.2
	43	H	1250	40	55	980	900	15	36	22	8.3	500	—	680.4
	44	H	1250	40	40	1010	900	15	50	11	5.3	450	—	665.0
	45	I	1230	70	60	900	950	5	7	103	82.6	650	483.9	712.3
	46	I	1230	50	70	950	950	5	16	36	26.0	640	463.2	702.4
	47	I	1230	40	60	990	950	5	30	28	10.8	500	—	687.0
	48	I	1230	40	40	1030	950	5	45	13	6.1	—	—	670.5

$K=10^{9.1}/t^{1.4}$：(℃/秒)、 $L=500-2.3\times t$：(℃)、 $M=720-1.1\times t$：(℃)

[0082]

[Table 6]

表　6

	番号	鋼	加熱温度(℃)	穿孔の加工度(%)	仕上げ圧延加工度(%)	仕上がり温度(℃)	加熱処理温度(℃)	加熱在炉時間(分)	肉厚t(mm)	800-500℃平均冷却速度(℃/秒)	K(℃/秒)	焼戻し温度(℃)	L(℃)	M(℃)
比較例	49	A	1250	60	*25	1000	950	20	25	14	13.9	550	442.5	692.5
	50	A	1250	60	40	*1100	950	20	24	18	14.7	600	444.8	693.6
	51	A	1250	60	40	1000	*1200	10	20	21	19.0	620	454.0	698.0
	52	A	1250	60	40	1000	1100	*60	25	15	13.9	600	442.5	692.5
	53	A	1250	60	70	860	900	15	7	90	82.6	*450	483.9	712.3
	54	A	1250	60	55	910	900	15	14	53	31.3	*—	467.8	704.6
	55	A	1250	60	40	930	900	15	22	20	16.6	*720	449.4	695.8
	56	A	1250	40	55	950	900	15	35	*5.2	8.7	700	—	681.5
	57	A	1250	40	40	970	900	15	48	*3.2	5.6	600	—	667.2
	58	*Q	1250	40	40	940	960	10	20	30	19.0	600	454.0	698.0
	59	*R	1250	40	40	940	960	10	24	31	14.7	600	444.8	693.6
	60	*S	1150	40	40	940	960	10	15	35	28.4	620	465.5	703.5
	61	*T	1250	40	40	940	960	10	18	25	22.0	550	458.6	700.2
	62	*U	1250	40	40	940	960	10	22	20	16.6	580	449.4	695.8
	63	*V	1250	40	40	940	960	10	20	24	19.0	640	454.0	698.0
	64	*W	1150	40	40	940	960	10	25	15	13.9	600	442.5	692.5

・ マーク*を付した数値、文字は本発明の範囲外であることを示す。
・ $K=10^{9.1}/t^{1.4}$：(℃/秒)、 $L=500-2.3\times t$：(℃)、 $M=720-1.1\times t$：(℃)

[0083]The tensile test carried out by an impact test extracting a with 4 mm in diameter, and a gage length of 20 mm test piece for tensile test again so that the lead in specimen thickness may be taken [piece / of 10 mm width and 5 mm thickness / of a half size Charpy test with 2mmV notch / each] in a center thick in parallel to a tube axial direction. The yield strength shown in the Table 8 - 10 which carry out a postscript, and the fracture transition temperature vTrs of base metal toughness are the both ends of a pipe, and central average value.

[0084]Among weldability, based on JIS Z 3158, the weld cracking sensitivity examination carried out stick welding (heat input 17 kJ/cm) with the preheat temperature of 50 ** to the piece of a slanting Y-globe type weld cracking test, and investigated the existence of the crack. In the Table 8 - 10 which carry out a postscript, that in which O and a crack generated what a crack does not generate was displayed by x.

[0085]After the examination about the toughness of a weld zone performs multilayer welding for the joined part of the pipes which carried out edge preparation from which the compared section serves as a V type in gas metal arc welding (heat input 23 kJ/cm), It carried out by extracting a specimen so that the notch bottom of a half size impact test specimen might agree from a welded joint part bond and a bond based on the macro dirty organization of a section in the position of HAZ by the side of a 1-mm base material. The fracture transition temperature vTrs (**) performed evaluation of this impact test.

[0086]Table 7 is a table showing the value in each 28 positions of the yield strength of the seamless steel tubes performed in rolling and the heat treatment condition which are shown in Table 3. The numbers P1 and P2 are the thing which heated just before direct quenching based on this invention, and the example which carried out direct quenching without the numbers P3 and P4 heat-treating after rolling equivalent to the conventional direct quenching.

[0087]
[Table 7]

表　7

番号	降伏強さ（kg／mm²）					標準偏差
	長手方向部位	周方向部位				
		1	2	3	4	
P1	a	55.6	55.9	55.2	55.3	0.68
	b	55.0	54.9	54.5	54.6	
	c	55.7	55.9	55.5	55.4	
	d	55.9	56.3	57.3	56.5	
	e	56.0	56.5	56.9	56.9	
	f	56.7	56.6	55.9	56.2	
	g	55.8	56.2	55.7	55.6	
P2	a	54.9	54.8	56.6	54.6	0.75
	b	54.6	55.8	55.7	55.3	
	c	56.1	56.0	55.4	55.5	
	d	56.1	55.0	55.9	55.9	
	e	55.6	55.6	56.8	56.4	
	f	57.3	57.1	55.5	56.5	
	g	57.0	56.9	56.1	56.2	
P3	a	49.1	53.3	49.7	48.9	1.87
	b	50.9	53.5	52.8	50.4	
	c	52.6	53.6	51.1	53.4	
	d	52.8	55.5	50.8	53.6	
	e	55.3	52.2	51.9	55.9	
	f	53.1	55.5	54.3	54.7	
	g	50.4	53.1	52.5	49.7	
P4	a	49.2	51.3	50.9	48.2	2.09
	b	51.7	53.2	52.0	50.1	
	c	51.3	51.7	51.0	49.2	
	d	54.1	54.4	51.4	54.2	
	e	54.6	56.0	55.1	52.0	
	f	50.6	56.2	51.7	55.3	
	g	53.5	53.7	54.3	53.7	

[0088]Drawing 2 - drawing 5 are drawings in which the yield strength in seamless-steel-tubes each position of the numbers P1-P4 is shown. The numbers P1 and P2 which are examples of this invention serve as a steel pipe of the performance in which dispersion is small and homogeneous also about a hoop direction, also about the longitudinal direction. On the other hand, what applied conventional direct quenching like the numbers P3 and P4 has large dispersion, while a longitudinal direction and the hoop direction of the value of yield strength itself are low. Although the steel A which all controlled hardenability in consideration of weldability was used for these numbers P1-P4, if direct quenching accompanied by heat-treatment is not performed after rolling like this invention method to steel with such low hardenability, they show that a homogeneous steel pipe is not obtained with high intensity.

[0089]Table 8 (numbers 1-24) and 9 (numbers 25-48) is a table showing the test result about what applied this invention method shown in Table 4 and 5, respectively.

[0090]These results show that the almost same yield strength is obtained, if it is the same steel by carrying out tempering temperature within the limits of this invention. Base metal toughness, weld cracking sensitivity, and the toughness of the weld zone are also excellent.

[0091]
[Table 8]

表　8

	番号	鋼	降伏強さ (kgf/mm²)	母材靭性 vTrs (℃)	斜め拘束割れ試験結果	溶接継手部ボンドの靭性 vTrs (℃)	HAZ 1mm 靭性 vTrs (℃)
本発明例	1	A	55.5	-83	○	-66	-74
	2	A	57.4	-76	○	-58	-62
	3	A	56.7	-68	○	-44	-55
	4	A	57.5	-73	○	-49	-57
	5	A	55.5	-82	○	-66	-71
	6	A	57.1	-64	○	-39	-54
	7	A	55.4	-57	○	-36	-41
	8	B	61.4	-72	○	-56	-56
	9	B	62.2	-81	○	-63	-65
	10	B	61.7	-69	○	-51	-55
	11	B	61.7	-81	○	-64	-69
	12	B	62.6	-72	○	-55	-62
	13	B	63.3	-64	○	-41	-56
	14	B	63.4	-70	○	-50	-58
	15	C	55.5	-81	○	-63	-69
	16	C	55.9	-78	○	-61	-63
	17	C	56.8	-78	○	-60	-68
	18	C	55.6	-67	○	-44	-57
	19	C	56.4	-77	○	-54	-67
	20	C	57.9	-60	○	-42	-49
	21	C	57.6	-60	○	-39	-44
	22	D	65.1	-66	○	-45	-55
	23	D	66.2	-69	○	-45	-58
	24	D	67.4	-57	○	-41	-44

[0092]

[Table 9]

表　9

	番号	鋼	降伏強さ (kgf/mm²)	母材靭性 vTrs (℃)	斜め拘束割れ試験結果	溶接継手部ボンドの靭性 vTrs (℃)	HAZ 1mm 靭性 vTrs (℃)
本発明例	25	D	65.3	-69	○	-47	-53
	26	D	67.6	-69	○	-49	-55
	27	D	67.5	-65	○	-47	-53
	28	E	56.6	-77	○	-56	-66
	29	E	57.8	-82	○	-66	-68
	30	E	58.8	-83	○	-61	-66
	31	E	57.5	-79	○	-62	-66
	32	E	56.4	-75	○	-55	-63
	33	F	48.8	-75	○	-52	-67
	34	F	48.3	-80	○	-60	-70
	35	F	48.8	-66	○	-43	-51
	36	F	47.8	-64	○	-42	-54
	37	G	50.0	-74	○	-58	-56
	38	G	50.6	-84	○	-61	-68
	39	G	50.4	-62	○	-43	-54
	40	G	50.1	-61	○	-42	-44
	41	H	70.3	-79	○	-62	-62
	42	H	71.7	-71	○	-48	-58
	43	H	70.5	-64	○	-45	-48
	44	H	71.7	-56	○	-35	-39
	45	I	59.4	-71	○	-47	-57
	46	I	58.7	-87	○	-65	-73
	47	I	58.3	-65	○	-46	-54
	48	I	59.5	-57	○	-33	-42

[0093]Table 10 (numbers 49-64) is a table showing the test result of the pipe manufactured on condition of besides the range of this invention shown in Table 6. Among front [the], the numbers 49-57 manufacture a manufacturing method on condition of besides the range of this invention, although the chemical composition of steel occurs within the limits of this invention.

[0094]The numbers 49-52 are outside the range of this invention after finishing strip processing in either finish temperature, heat-treatment temperature and heating in-furnace time before long.
As a result, toughness is inferior.
Although the numbers 53-57 are the cases where thickness is changed systematically, since the average cooling rate and tempering temperature of direct quenching are outside the range of this invention, intensity changes a lot and is inferior in both toughness and weldability as thickness changes.

[0095]Since the numbers 58-64 have the chemical composition of steel out of the range of this invention, especially their toughness of a weld zone is low, and they are high. [of weld cracking sensitivity]

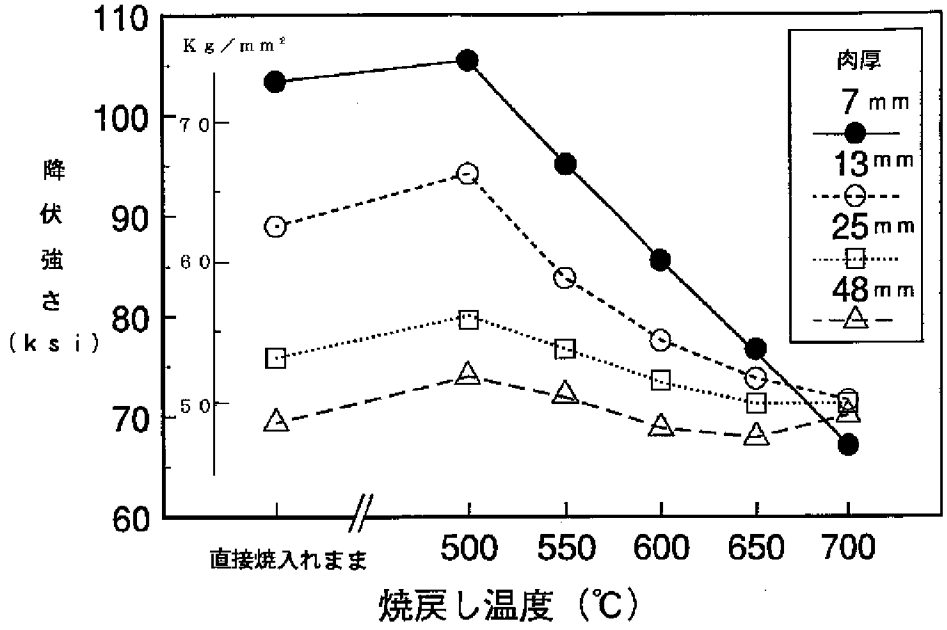
[0096]
[Table 10]

表　10

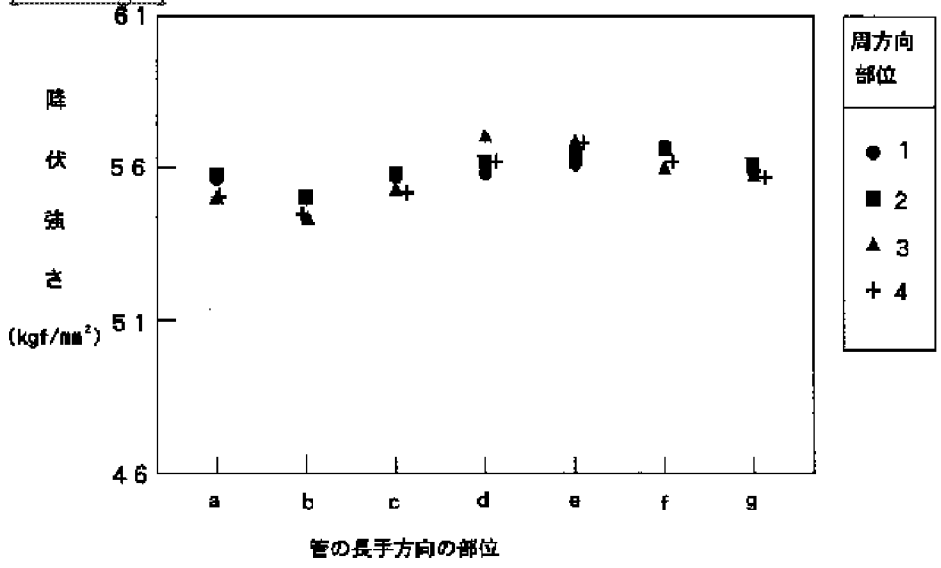
	番号	鋼	降伏強さ (kgf/mm²)	母材靱性 vTrs (℃)	斜め拘束割れ試験結果	溶接継手部ボンドの靱性 vTrs (℃)	HAZ 1mm靱性 vTrs (℃)
比較例	49	A	54.3	-34	○	-16	-20
	50	A	54.8	-28	○	+3	-11
	51	A	57.6	-10	○	+5	-3
	52	A	55.2	-29	○	-7	-16
	53	A	72.8	-38	×	-18	-28
	54	A	62.1	-35	×	-29	-29
	55	A	46.7	-41	○	-25	-27
	56	A	44.3	-42	○	-23	-32
	57	A	41.2	-37	○	-21	-22
	58	Q	72.0	-36	×	-15	-27
	59	R	76.5	-27	×	-5	-14
	60	S	88.8	-2	×	14	13
	61	T	90.7	-8	×	12	9
	62	U	67.4	-35	×	-24	-27
	63	V	70.2	-30	×	-19	-26
	64	W	85.1	-10	×	10	3

[0097]
[Effect of the Invention]By this invention method, since the high intensity high toughness seamless steel tubes which were excellent in weldability are stabilized, it can manufacture now for high productivity and the wide thick range can be manufactured with the still more nearly same steel, an inventory billet can be decreased, and a very

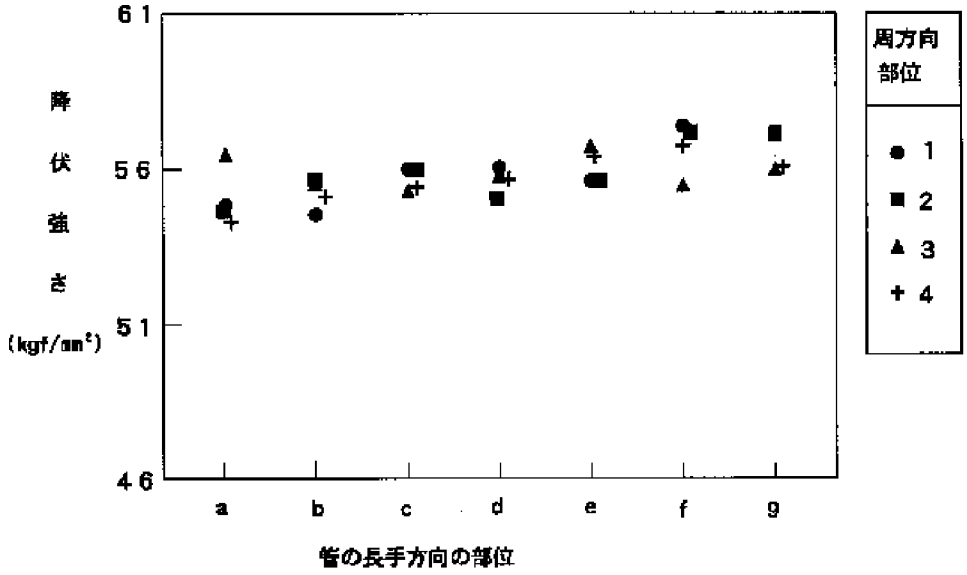
desirable effect is brought to development of the industry of this field.



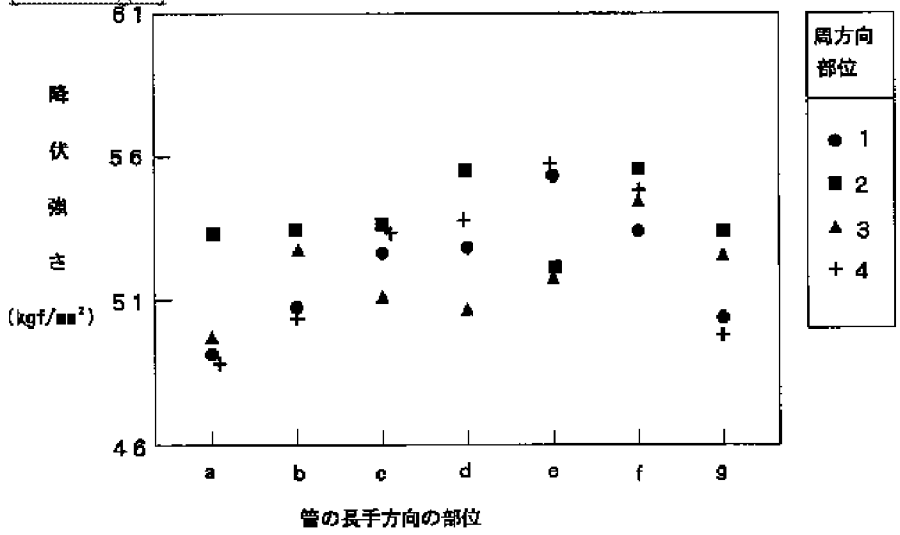
[Drawing 2]



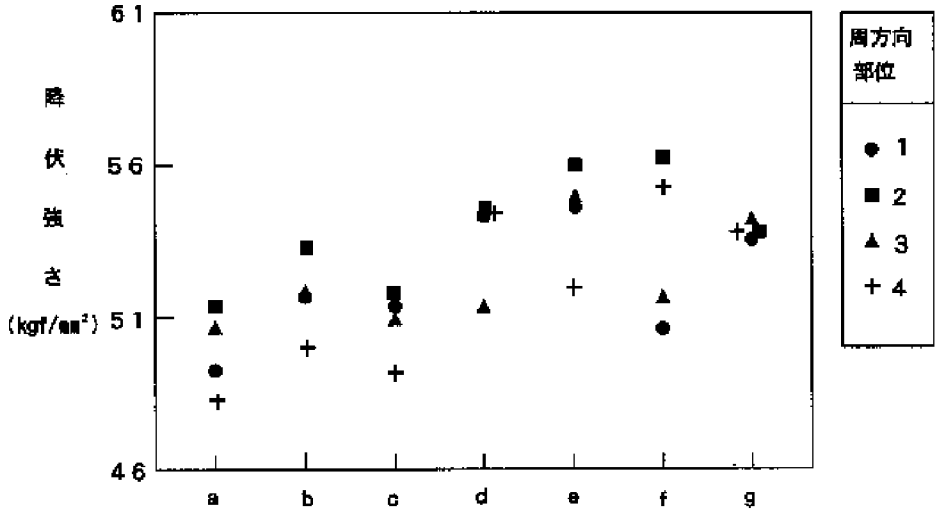
[Drawing 3]



[Drawing 4]



[Drawing 5]


61
56
51
46
降伏強さ
(kgf/mm²)
a
b
c
d
e
f
g
周方向部位
1
2
3
4